Lower Chickahominy River Bacteria TMDL
Summary Documents For Discussion 1/4/16 @ 2pm
Edited on 1/8/16 to clarify the options for MS4 WLA Calculation in Section 2

In attendance: Margaret Smigo (DEQ), Jennifer Palmore (DEQ), Kelley West (DEQ), Mac Sisson (VIMS), Jian Shen (VIMS), Yuan Zhao (VIMS), Ashley Hall (EEE Consulting, for VDOT), Suzanne Dyba (James City County), Ron Stowell (watershed resident)
Not in attendance: Donald Rice (Newport News Water Service Authority)
All TAC members were asked to notify DEQ if they would like to participate in the call - only those who are noted above expressed an interest.

Contents:

Section 1 – Seasonality of Sources

To evaluate the seasonal variation of the bacterial loadings in the Chickahominy River, the monthly averaged bacterial concentration at each observation station (Figures 1 and 3) is computed and the results are presented in Figures 2 and 4. Based on the monthly distributions of bacterial concentrations, no persistent seasonality of the bacteria concentration can be seen. High bacterial concentrations occur in January, May, June, and November at different stations. This could be due to limitation of the data or some other unknown reasons. It appears that the wildlife behavior in the Lower Chickahominy River Watershed differs from Poquoson River and Eastern Shore area, where migrating birds dominate the seasonal variation. Because the hydrology varies seasonally (i.e., low flow in the summer and high low in spring), it is difficult to know whether the effects of bird migration and variation of hydrological processes dominate the seasonal variation based on data analysis.

For livestock loads, the EPA software “FecalTool” is used to estimate monthly loading. It considers monthly variations of grazing, feedlot confinement, and direct stream access. The seasonal variation will be further assessed using numerical model so that the effect of hydrological process in this watershed can be assessed. Some adjustment will be implemented for some watersheds during model calibration where clear seasonality is observed. We have discussed with the Newport News Water Authority aspects of flow effects and have contacted VDH for additional information of seasonal inputs. The seasonal variation of bacterial sources will be discussed in the TMDL report.

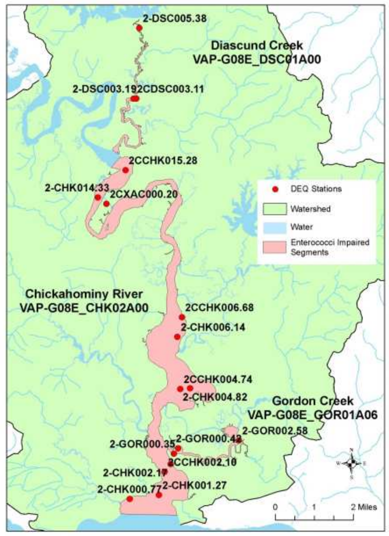

Figure 1 VADEQ Monitoring Stations in the Enterococci Impaired Waters.

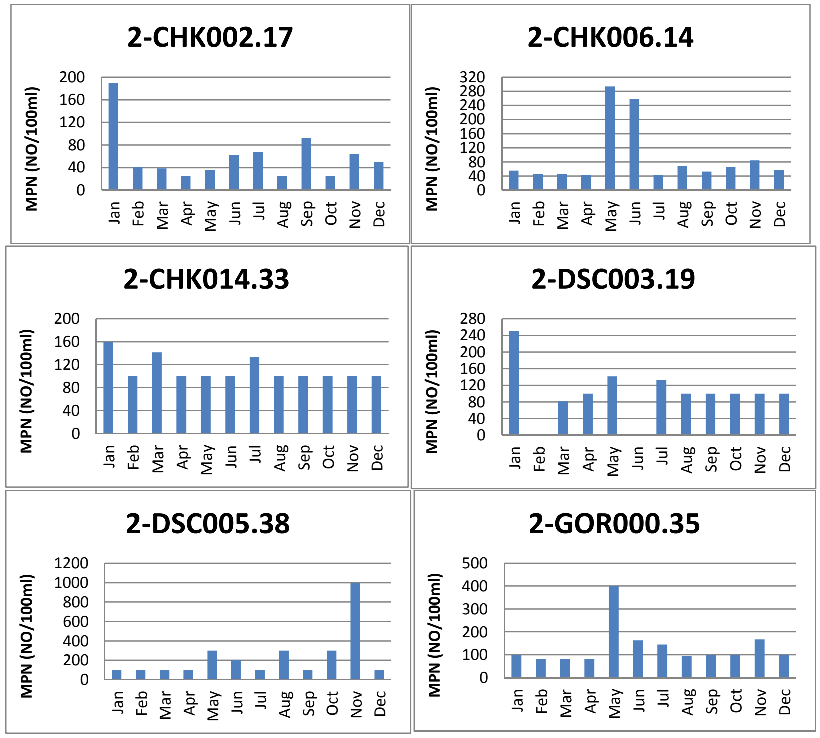

Figure 2. Monthly Enterococci Concentration Distribution

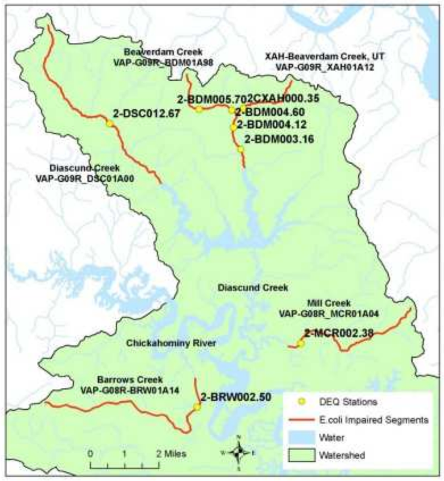

Figure 3 VADEQ Monitoring Stations in the *E. coli* Impaired Waters.

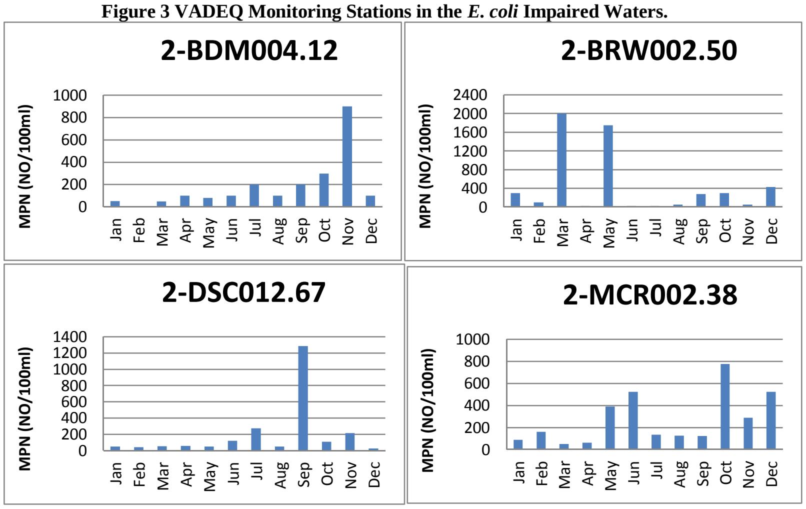

Figure 4. Monthly *E. Coli* Concentration Distributions

Section 2 - MS4 WLA Preliminary Review *(revised version*)

There are two Municipal Separate Storm Sewer System (MS4) permits in the area owned by James City County and the Virginia DOT (roads within James City County). The James City County provided a GIS map file of their MS4 regulated area. The loading of VDOT roads can be calculated based on the road length and a typical buffer width (e.g., 20 meters on each side of the road), which coincides with the service area provided by the County. Due to the continuity and overlap of roads and the County's service area, it is the preference of DEQ to aggregate the waste load allocations (WLAs) of these two facilities. The MS4 loading will be estimated based on urban landuse in the MS4 regulated area. The allocation for MS4 permits will be determined based on the partitioning of the total loading between total landuse and urban landuse within the MS4 regulated area (provided by the James City County and VDOT). The urban landuse of the MS4 regulated area is comprised of the sum of Developed High Intensity, Developed Medium Intensity, and Developed Low Intensity areas, and Developed Open Space based on 2011 NLCD data. The Waste Load Allocations for the MS4s will be provided when model simulation and calculation of TMDLs are completed.

Two options can be used to allocate MS4 loads, which are given in the following examples.

Option 1. Allocate MS4 loading based on partition of urban landuse and non-urban landuse (as defined by NLCD 2011) within the regulated MS4 area (area GIS layers are provided by James City County and VDOT) based on landuse data. This approach depends on reliability of landuse data used for computing the partition.

Total TMDL: 17,021,276.6 # per day (modeled)

Future allocation (1% of TMDL) = 170,212.7 # per day

MOS (5% of TMDL) = 851,063.8 # per day

Total Loadings for allocation = 1,600,000 # per day

Loading from urban land = 10,000,000 # per day

Loading from nonurban land = 6,000,000 #per day

Total area = 100 ac

Urban landuse = 50 ac

Nonurban landuse = 50 ac

MS4 regulated area = 30 ac

Urban landuse within MS4 regulated area is 90% of the total regulated area

Urban landuse within MS4 regulated area = 90% x 30 ac = 27 ac

MS4 loading = 27/50 x 10,000,000 = **5,400,000** # per day

LA = 16,000,000 – 5,400,000 = 10,600,000

The Total maximum daily loadings (Counts per day) are as follows:

TMDL		LA		WLA		FA (1%)		MOS (5%)
17,021,276.6	=	10,600,000	+	5,400,000	+	170,212.7	+	851,063.8
MS4 James City (VAR040037) = **5,400,000** (aggregated wasteload allocation) VDOT (VAR040115)								

TMDL = Total maximum daily loadings
LA = Load Allocation (nonpoint source)
WLA = Wasteload Allocation (Point source)
FA = Future Allocation, which is 1% of allowable load (aka Future Growth)
MOS = Margin of Safety

Option 2. Allocate loading within regulated MS4 area (area GIS layers are provided by James City County and VDOT) to MS4. Because the dominant landuse within the MS4 area is urban landuse, it is reasonable to allocate *all* loading to MS4, as opposed to using a partitioning method demonstrated in option 1.

Total TMDL: 17021276.6 # per day

Future allocation (1%) = 170,212.7 # per day

MOS (5%) = 851,063.8 # per day

Total Loadings for allocation = 1,600,000 # per day

Loading from urban land = 10,000,000 # per day

Loading from nonurban land = 6,000,000 # per day

Urban landuse = 50 ac

MS4 regulated area = 30 ac

MS4 loading = 30/50 x 10,000,000 = **6,000,000** # per day

LA = 16,000,000 – 6,000,000 = 10,000,000

The Total maximum daily loadings (Counts per day) are as follows:

TMDL		LA		WLA		FA (1%)		MOS (5%)
17,021,276.6	=	10,000,000	+	6,000,000	+	170,212.7	+	851,063.8
MS4 James City (VAR040037) = **6,000,000** (aggregated wasteload allocation) VDOT (VAR040115)								

Section 3 - BACTERIA SOURCE ASSESSMENT

A primary component of TMDL development for the Chickahominy River is the evaluation of potential sources of bacteria in the watershed. The source assessment was used as the basis of model development and the ultimate analysis of TMDL allocation options. In evaluation of sources, a watershed approach was applied and loads were characterized by the best available information, landowner and citizen input, literature values, and local government agencies. The source assessment chapter is organized into point and nonpoint sections and summarizes the available information and interpretation for the analysis. A detailed representation of the following sources in the model is discussed in Appendix C. To adequately represent the spatial variation in the watershed, the lower Chickahominy River Watershed drainage area was divided into twenty six (26) subwatersheds (Figure 3.1). Source assessment is conducted on the subwatershed level where estimates of all potential bacteria sources are compiled for each individual subwatershed. Table 3.1 lists the subwatersheds of each bacteria impaired water segment by the localities with which they overlap.

Table 3.1 Subwatersheds Contained by Each Impaired Area and localities they overlap

Impaired Segment	Subwatersheds
Chickahominy River	1-26
Diascund Creek (Nontidal)	1
Beaverdam Creek	2, 3
UT Beaverdam Creek	3
Diascund Creek (Tidal)	1-6,9-11
Mill Creek	11
Barrows Creek	17
Gordon Creek	22
Locality	**Overlapping Subwatersheds**
Charles City County	7, 16-20, 23-25
James City County	5, 10-15,21,22,26
New Kent County	1-4, 6, 8, 9

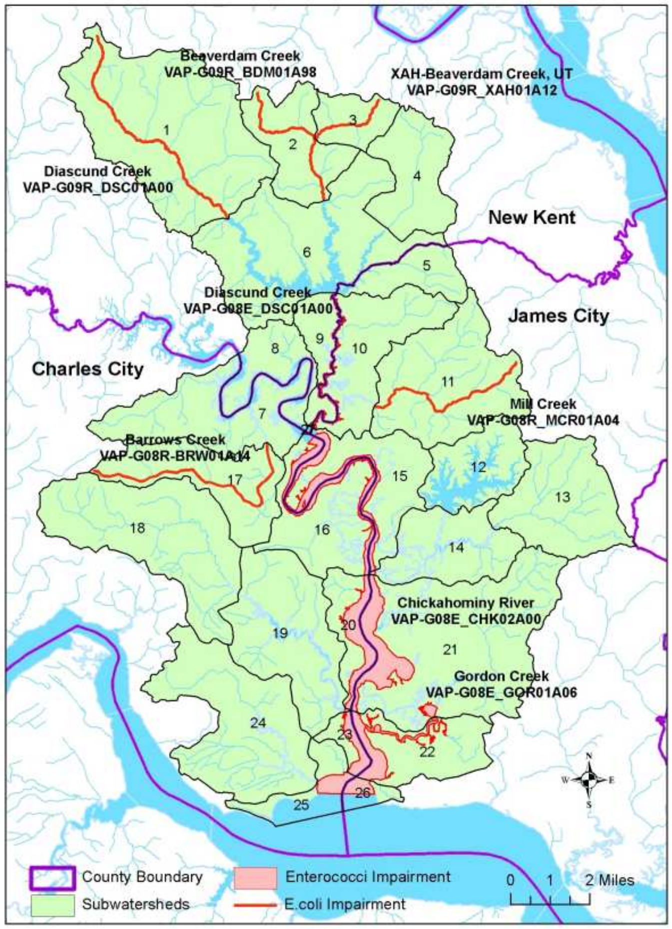

Figure 3.1 Subwatersheds Delineated for Modeling in the Lower Chickahominy River Watershed.

3.1 Point Sources

There are sixteen permitted point sources that discharge to surface water bodies in the Lower Chickahominy River watershed. Nine of them (Table 3.2) will be assigned with bacteria wasteload allocations (WLAs).

Table 3.2 Permits That Need Bacteria WLA in the Chickahominy River Watershed.

Permit Number	Facility Name	Permit Type	Category	Subwatershed	Designed Flow (MGD)
VA0080233	Hideaway STP	Minor Municipal	VPDES-IP	16	0.039
VAG403039	Single Family Home	General Permit	Domestic Discharger	15	0.001
VAG404050	Single Family Home	General Permit	Domestic Discharger	16	0.001
VAG404144	Single Family Home	General Permit	Domestic Discharger	23	0.001
VAG404152	Single Family Home	General Permit	Domestic Discharger	23	0.001
VAG404198	Single Family Home	General Permit	Domestic Discharger	7	0.001
VAG404284	Single Family Home	General Permit	Domestic Discharger	6	0.001
VAR040037	Locality urbanized service area – James City	General Permit	MS4-Phase II	Various	SW Only - Use model
VAR040115	VDOT roads within James City County	General Permit	MS4-Phase II	Various	SW Only - Use model

3.2 Nonpoint Sources

In the Lower Chickahominy River watershed, sources of bacteria include residential sewage disposal systems, sanitary sewer overflows (SSOs), biosolids, pets, wildlife, livestock, recreational boating, and straight pipes. Sources were identified and enumerated. Where appropriate, the spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal bacteria is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal bacteria to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity.

For the subwatersheds located within the James City County, the number of homes that have septic tanks are based on the data provided by the County. The accuracy of the estimates was enhanced by the geographic information showing the locations of septic systems.

For the subwatersheds located within the Charles City and New Kent Counties, the “911” street address GIS layers were obtained from the County offices. Since the GIS layer identifies individual houses located within the Chickahominy River watershed, it provides a more accurate estimation of septic tank numbers. It was discussed in the TAC meeting that in the northern part of the watershed, New Kent County has small areas that are serviced by wastewater treatment facilities. The service map was provided by New Kent Department of Public Utilities and overlaid with the “911” GIS layer to exclude the public service area from septic systems. There is no public sewage service area in Charles City County, therefore, all 911 addresses are assumed to have septic systems. Another subwatershed within the watershed, Morris Creek (Subwatersheds 18 and 19), underwent a bacteria TMDL by DEQ in 2009. Therefore, the number of septic tanks noted in the TMDL for these two subwatersheds has been used. There are a total of 4,314 septic tanks in the entire area. Table 3.3 lists the number of septic tanks by subwatershed.

Table 3.3 Total Number of Septic Tanks by Subwatershed.

Subwatershed	Number of Septic Tanks	Subwatershed	Number of Septic Tanks
1	268	**14**	61
2	106	**15**	439
3	20	**16**	83
4	101	**17**	114
5	64	**18 and 19 (Morris Creek)**	97
6	346		
7	58	**20**	4
8	382	**21**	195
9	271	**22**	41
10	435	**23**	38
11	400	**24**	57
12	289	**25**	8
13	436	**26**	1

A failure rate of 10% is used according to the data provided by the James City County. The average number of persons per household is obtained from US Census Bureau (USCB, 2015). The septic loading rate is estimated as the septic overcharge flow rate of 70 gal/person/day (EPA, 2001b) multiplying the overcharge concentration of 1.0×10^6 counts/100 ml (MapTech, 2010; EPA, 2001b). The fecal coliform loading from the failed septic tank systems then is estimated as the product of the number of failed septic tanks, the number of persons per household, and the septic loading rate.

3.2.2 Recreational Boating

Marina and boating activities can contribute bacteria loading when their wastes are not adequately collected in pump stations or the pump stations do not work properly. The open water area in each subwatershed and county was estimated using NLCD (2011) landuse category “Open Water”. Bacteria contributions are expected to occur in subwatersheds containing the “Open Water” category. Information of the number of registered boats in each county was obtained from VA-DGIF personnel. These numbers were divided by the county open water area and then multiplied by the subwatershed open water area to estimate the number of boats in each subwatershed (Table 3.4). To calculate an estimate of loading, the method of VA-DEQ (2014) was adopted. On average there are 3 persons per boat, only 10% of the boats will illicitly discharge and therefore contribute to the loading, and a fecal coliform production rate of 2.0E+09 counts/day/person. The total loading contribution from boats was estimated as the product of the aforementioned 3 numbers.

Table 3.4 Number of Boats in the Subwatershed of Lower Chickahominy River.

Subwatershed	Number of Boats	Subwatershed	Number of Boats
1	4	**14**	36
2	0	**15**	111
3	0	**16**	80
4	2	**17**	2
5	15	**18 and 19 (Morris Creek)**	27
6	366		
7	56	**20**	85
8	157	**21**	244
9	36	**22**	100
10	31	**23**	35
11	5	**24**	14
12	145	**25**	104
13	5	**26**	60

3.2.3 Straight Pipes

Besides public sanitary sewer and septic tank systems, the sewage from a house may also be disposed by straight pipe, which consists of untreated, or raw sewage being directly discharged by pipe to a waterway. Generally, when a septic system fails the property owner contacts the VDH to initiate a remedy. Depending on the circumstance, VDH may facilitate a repair of the failing system, initiate a permit for the construction of a new alternative system, or if service is available, the owner may opt to connect to public sewer. However, straight pipes may be adapted to a dwelling by an owner as an inexpensive and illegal means of disposing household sewage. Because any illicit discharge of untreated human waste is illegal under state law due the potential impact to human health and wildlife, straight pipes are prioritized for load reduction in the TMDL model. Unless VDH is notified, corrective actions with the property owner may not be initiated. Therefore, it is possible that not all of these are straight pipes are present in a watershed at any given time as the number of failing systems occurring at a given time may also fluctuate (see section 3.2.1).

For this study, the method of straight pipe estimation has been adopted from the Upper York River bacteria TMDL (The Louis Burger Group Inc., 2010). The 1990 census data (USCB, 2011) documents the distribution of houses on sewage systems, septic systems, and other means (considered to be straight pipes). Assuming the percent distribution of the current sewage disposal method is the same as that of 1990, the 1990 estimated distribution (1.90% for straight pipes for Virginia) was multiplied by the estimated number of houses in each subwatershed to estimate the number of houses with straight pipes (Table 3.5).

The average number of persons per household by county was obtained (USCB 2015; Charles City, 2.59; James City, 2.47; New Kent, 2.65). For each subwatershed, the total number of persons utilizing straight pipes was then estimated through a calculation where the number of persons per household were multiplied by the number of houses with straight pipes. According to a report by the EPA (2001), about

70 gallons/person/day of water is discharged by this means. According to VA-DEQ (2014), the raw sewage fecal coliform concentration is 2,700,000 MPN/100ml. The bacteria loading from straight pipes can then be estimated as the product of total number of persons utilizing straight pipes, the water discharge rate of each person, and the raw sewage fecal coliform concentration.

Table 3.5 Number of Straight Pipes in Each Subwatershed in the Lower Chickahominy River Watershed.

Subwatershed	Number of Straight Pipes	Subwatershed	Number of Straight Pipes
1	5	**14**	1
2	2	**15**	8
3	0	**16**	2
4	2	**17**	2
5	1	**18**	1
6	7	**19**	2
7	1	**20**	0
8	7	**21**	4
9	5	**22**	1
10	8	**23**	1
11	8	**24**	1
12	5	**25**	0
13	8	**26**	0

3.2.4 Sanitary Sewer Overflows (SSOs)

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge, or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity or the capacity is reduced by a blockage, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system, or due to infrastructure failure. Failures are typically addressed by counties/municipalities when they occur and programs exist that intend to repair damaged sewer lines and resolve high maintenance problems. Table 3.6 details the volume of overflows reported since year 2010 from VA-DEQ.

Table 3.6 The SSOs in the Lower Chickahominy River Watershed Since Year 2010.

Permit Number	Permitee	Date	Sub-watershed	Volume (Gallons)
VA0080233	Hideaway STP	2/5/2010	18	500-1000
VA0080233	Hideaway STP	8/27/2011 -9/1/2011	17	1400-20000
VA0080233	Hideaway STP	7/31/2013 -8/5/2013	16	22500
VA0080233	Hideaway STP	11/20/2013	18	Not reported, but limited according to the comments
VA0080233	Hideaway STP	9/25/2013	18	250
VA0080233	Hideaway STP	1/29/2014	18	350
VA0080233	Hideaway STP	3/8/2014	18	Not reported, but limited according to the comments
VA0080233	Hideaway STP	9/3/2014	18	<1440

To estimate the bacteria loading from SSO, the method of DEQ (2014) is adopted for conservative purposes. The accumulative spillage distribution using available data is plotted (Figure 3.2). The loading corresponding to a 95% spillage volume (22,000 gallons) is estimated as 25% raw sewage and 75% non-raw sewage (communication with DEQ personnel). The fecal coliform concentrations for raw sewage and non-raw sewage, and the total loading are listed in Table 3.7. The total loading is distributed to each SSO according to their volume ratio. It can be seen that on average SSO spills occurred less than 2 times each year, and they do not contribute significantly on a daily basis. However, when spillage occurs, it can result in a short-term increase of fecal coliform concentration in the receiving waters.

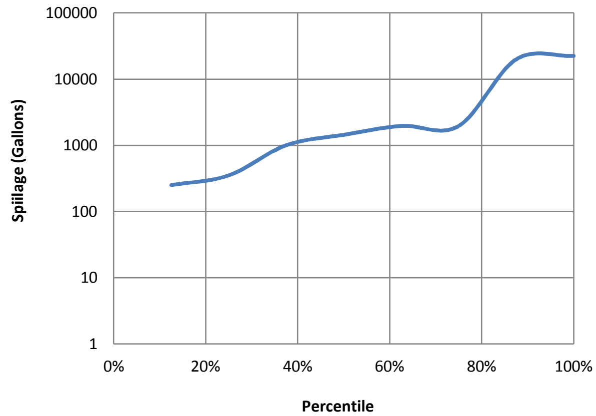

Figure 3.2 Cumulative Frequency Distributions of SSOs in the Lower Chickahominy River Watershed.

Table 3.7 Fecal Coliform Information for SSOs in the Lower Chickahominy River Watershed

95% Volume (Gallons)	Raw Sewage Concentration (Counts/100ml)	Non-Raw Sewage Concentration (Counts/100ml)	Fecal Coliform Load (Counts/Day)
22,000	2,700,000	500,000	8.7×10^{11}

3.2.5 Biosolids

Between 2010 and 2014, biosolids were applied to fields within the Lower Chickahominy River watershed (Table 3.8). The total application amount is 6,644 wet tons. Table 3.5 lists the total application amount by subwatershed. To DEQ's knowledge, among the three counties, only Charles City has biosolids application permits. Biosolids are required to be spread according to sound agronomic requirements with consideration for topography and hydrology. All applications are done in accordance with an approved Nutrient Management Plan. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids), as compared with approximately 240 cfu/g-dry for dairy waste; however, actual applications may have densities far less than this amount. Application rates must be limited to a maximum of 15 dry tons/acre per three-year period.

In order not to overestimate the loadings, biosolids were modeled as having a fecal coliform concentration of 157,835 cfu/g, the mean value of measured biosolids concentrations observed in several years of samples supplied by VA-DEQ for sources applied during 2001 to 2011. An assumption of proper application was made, wherein no biosolids were modeled as being spread in stream corridors.

Table 3.8 Biosolids Application by Subwatershed from 2010 to 2014 in Charles County.

Subwatershed	Year	Total Biosolid Application Weight (Wet Tons)	Fecal Coliform Load (Counts/Day)
7	2010	726	3.1×10^{11}
	2014	469	2.0×10^{11}
17	2014	2,329	1.0×10^{12}
18	2010	991	4.3×10^{11}
	2011	934	4.0×10^{11}
	2014	1,195	5.2×10^{11}

3.2.6 Pets

According to a previous study (VA-DEQ, 2012), cats and dogs were the predominant contributors of fecal coliform in the Chickahominy River and Tributaries watershed, and the fecal coliform daily loadings of dogs were 10^6 higher than those of the cats. Therefore, dogs are the only pet considered in this study. The numbers of dogs (i.e., numbers of dog licenses) of Charles City, James City, and New Kent Counties were obtained from each county's Treasurer Office. The number of dogs in each subwatershed is calculated by dividing the total number of dogs in the county by the county urban area, and then multiplying the subwatershed urban area. As the Morris Creek (Subwatersheds 18 and 19) bacteria TMDL (VA-DEQ, 2009) has been finished, the number of dogs in these two subwatersheds is used. Table 3.9 lists the dog numbers by subwatershed. The fecal coliform production rate used is 4.0×10^9 counts/dog/day (LIRPB, 1978), with 23% of the total dog feces being subject to runoff (VA-DEQ, 2014). The bacteria load is calculated as the product of the dog number, the 23% runoff rate, and the production rate.

Table 3.9 Number of Dogs in Each Subwatershed in the Lower Chickahominy River Watershed.

Subwatershed	Number of Dogs	Subwatershed	Number of Dogs
1	371	**14**	8
2	101	**15**	29
3	47	**16**	52
4	72	**17**	78
5	29	**18 and 19 (Morris Creek)**	425
6	179		
7	52	**20**	13
8	61	**21**	40
9	59	**22**	27
10	57	**23**	13
11	82	**24**	130
12	23	**25**	19
13	157	**26**	11

3.2.7 Wildlife

The predominant wildlife species in the Lower Chickahominy River watershed were determined through consultation with wildlife biologists from the VA-DGIF, citizens from the watershed, and other state and local officials. The landuse information of National Land Cover Database (NLCD) 2011 was used to determine the habitat area/location of each wildlife type within each subwatershed. The 15 landuse categories of Lower Chickahominy River were merged into 6 categories of developed, forest, cropland, pasture/hay, wetland, and other. The habitat of each wildlife type falls in one or more of these 6 landuse categories. As Morris Creek (Subwatersheds 18 and 19) bacteria TMDL (VA-DEQ, 2009) has been finished, the number of wildlife in these two subwatersheds is used in this study. The density of each species is listed in Table 3.10. Table 3.11 depicts the wildlife numbers by subwatershed.

Table 3.10 The Densities and Fecal Coliform Production Rates of the Wildlife Species in the Lower Chickahominy River Watershed.

Species	Density	Reference of Density	Production Rate (Counts/Animal/Day)	Reference of Production Rate
Deer	Charles City: 33/mile^2 James City: 26/mile^2 New Kent: 31/mile^2	VADGIF, 2007	5.00E+08	VADEQ, 2007
Duck	1.532/km^2	VADEQ, 2009	2.43E+09	VA Tech, 2000
Goose	1.969/km^2	VADEQ, 2009	4.90E+10	USEPA, 2001b
Beaver	4.8/mile	VADEQ, 2009	2.50E+08	ASAE, 1998
Raccoon	Inside Buffer: 0.078/acre Outside Buffer: 0.016/acre	VADEQ, 2014	1.25E+08	Best Professional Judgment
Muskrat	10/acre	VADEQ, 2009	3.40E+07	VADEQ, 2007

3.2.7.1 Deer

The deer habitat is the entire watershed except open water and urban area. An average deer index by county was obtained from VADGIF (Charles City: 4.3, James City: 3.4, and New Kent: 4.1). The density was calculated as

$$Deer\ Number\ per\ Mile^2 of\ Habitat = -0.64 + (7.74 \times Average\ Deer\ Index)$$

The deer habitat area was determined by the GIS landuse data. The total number of deer in each subwatershed equals to the deer density multiplied by its habitat area. The total fecal coliform loading is calculated as the number of deer multiplied by its fecal coliform production rate.

3.2.7.2 Duck and Goose

The duck and goose habitats are the entire watershed. The density was multiplied by subwatershed area to get the total number in each subwatershed. The total fecal coliform loading is calculated as the total number of duck/goose multiplied by their production rates. Depending on the model calibration result, their density for each month may need to be adjusted to incorporate the seasonal migration effect.

3.2.7.3 Beaver

The habitat of beaver is the riparian zone, which is the interface between land and a stream. The river mile of each subwatershed was determined by measuring the total river length using GIS software. The number of beaver in each subwatershed equals to its density multiplies the river mile. The total fecal coliform loading is calculated as the number of beaver in each subwatershed multiplied by its production rate.

3.2.7.4 Raccoon

The raccoon habitats are wetlands and forest. A 600-foot buffer zone was used along the streams and ponds in the Lower Chickahominy River watershed. Different densities were assigned inside and outside of the buffer due to habitat preferences. The numbers of raccoon outside and inside the buffer within each subwatershed was calculated by multiplying their respective density by the habitat area. These two numbers were added together to obtain the total number in each subwatershed. The fecal coliform loading is calculated as the number of raccoons multiplied by its production rate.

3.2.7.5 Muskrat

The muskrat habitat is wetlands only. They are most active at night or near dawn and dusk. They are prolific breeders that have two or three litters a year of six to eight young each, which explain their high numbers. The density was multiplied by subwatershed habitat area to get the total number. The fecal coliform loading in each subwatershed is calculated as the total number multiplied by its production rate.

Table 3.11 Total Number of Wildlife in Each Subwatershed in the Lower Chickahominy River Watershed.

Subwatershed	Deer	Duck	Goose	Beaver	Raccoon	Muskrat
1	434	63	81	33	449	8,220
2	135	19	25	21	136	2,893
3	64	9	12	11	65	1,381
4	145	20	26	18	138	2,513
5	58	11	14	10	65	1,337
6	327	51	66	192	318	5,446
7	210	29	38	54	205	10,359
8	71	13	17	54	82	6,218
9	54	9	11	42	67	4,041
10	136	25	32	42	181	10,179
11	221	38	48	23	241	6,665
12	73	18	23	165	31	585
13	142	29	37	20	166	4,254
14	129	22	28	66	192	11,513
15	110	22	29	42	152	10,748
16	151	23	30	42	172	14,329
17	192	25	32	32	133	5,667
18 and 19 (Morris Creek)	450	50	65	65	500	9,800
20	47	10	13	19	48	1,332
21	348	65	83	43	466	25,277
22	93	19	25	67	110	7,995
23	16	4	5	9	17	752
24	321	42	54	38	226	15,018
25	40	10	13	6	20	1,386
26	4	3	4	4	5	578

3.2.8 Livestock

An inventory of the livestock of the Lower Chickahominy River watershed was conducted using data provided by United States Department of Agriculture (USDA, 2012), the Morris Creek bacteria TMDL, and citizens' input at the first public meeting and TAC meetings. The predominant types of livestock in the watershed are beef cattle, milk cattle, pigs, chickens, horses, and sheep/goats.

Initially, the number of each livestock species by county was obtained from USDA county data. The livestock number in a subwatershed was calculated as the county's livestock number divided by its habitat area, and multiplied by the subwatershed habitat area. As Morris Creek (Subwatersheds 18 and 19) bacteria TMDL (VADEQ, 2009) has been finished, the numbers of livestock in these two subwatersheds were used. These numbers were validated and updated by consulting with the citizens at the public and TAC meetings. The livestock habitat type and bacteria production rates are listed in Table 3.12. In all three counties farmers practice rotational grazing, which is part of the nutrient management plan. As a result, there is no manure application occurring watershed-wide. Table 3.13 lists the livestock number by subwatershed.

Table 3.12 Livestock Habitat Type and Fecal Coliform Production Rate (ASAE, 1998).

Livestock	Habitat	Production Rate (Counts/Animal/Day)
Beef Cattle	Pastureland, feedlots	1.04E+11
Milk Cattle	Feedlots	1.01E+11
Pigs	Feedlots	1.08E+10
Chickens	Feedlots	1.36E+08
Horses	Pastureland, feedlots	4.20E+08
Sheep/Goats	Pastureland, feedlots	1.20E+10

Table 3.13 Total Number of Livestock in Each Subwatershed in the Lower Chickahominy River Watershed.

Subwatershed	Beef Cattle	Milk Cattle	Pigs	Chickens	Horses	Sheep/Goats
1	0	1	0	0	0	0
2	0	1	0	0	0	0
3	0	0	0	0	0	0
4	0	1	0	0	0	0
5	**2**	**1**	**1**	**19**	**3**	**0**
6	0	1	0	0	0	0
7	0	0	0	0	0	0
8	0	1	0	0	0	0
9	0	0	0	0	0	0
10	**2**	**2**	**1**	**34**	**4**	**0**
11	**30**	**22**	**2**	**68**	**51**	**1**
12	**14**	**10**	**1**	**24**	**24**	**0**
13	**20**	**15**	**2**	**52**	**35**	**0**
14	**2**	**1**	**1**	**26**	**3**	**0**
15	**2**	**2**	**1**	**23**	**4**	**0**
16	0	6	0	0	0	100
17	45	6	0	0	0	100
18 and 19 (Morris Creek)	**20**	**0**	**0**	**20**	**1**	**185**
20	0	0	0	0	0	0
21	**11**	**8**	**3**	**80**	**18**	**0**
22	**1**	**1**	**1**	**21**	**2**	**0**
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	**0**	**0**	**0**	**1**	**0**	**0**

* Numbers in black are based on citizen update, and the numbers in blue are based on USDA county data. Morris Creek TMDL results are adopted. Numbers in blue will be further confirmed by counties.

3.2.9 Summary of Source Assessment

A summary of fecal coliform load from each source for all the impaired waters in the watershed is listed in Table 3.14. Table 3.15 summarizes the loads by county. Note that the SSO is estimated based on the 95th-percentile loading. As spillage occurred less than 2 times per year on average, it does not contribute significantly on a daily basis.

Table 3.14* Summary of Bacteria Loading by Source Type for Impaired Waters in the Lower Chickahominy River Watershed.

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Lower Chickahominy River (Subwatersheds 1-26)	**Wildlife**	Deer	3971	2.0E+12	2.6%
		Ducks	629	1.5E+12	2.0%
		Geese	809	4.0E+13	51.9%
		Beavers	1120	2.8E+11	0.4%
		Raccoons	4184	5.2E+11	0.7%
		Muskrats	168488	5.7E+12	7.5%
		Totals	179199	5.0E+13	65.1%
	Livestock	Totals	1143	1.5E+13	19.8%
	Pets	Dogs	2136	2.0E+12	2.6%
	Humans	Septic Tank Failures	4314	2.9E+12	3.8%
		Boating	1718	1.0E+12	1.3%
		Straight Pipes	96	1.8E+12	2.3%
		Biosolids	6644 (tons)	2.9E+12	3.8%
		SSOs	8	8.7E+11	1.1%
	Totals			**7.6E+13**	**100%**
Diascund Creek (Tidal) (Subwatersheds 1-6, 9-11)	**Wildlife**	Deer	1575	7.9E+11	3.2%
		Ducks	245	6.0E+11	2.4%
		Geese	315	1.5E+13	63.0%
		Beavers	393	9.8E+10	0.4%
		Raccoons	1660	2.1E+11	0.8%
		Muskrats	42675	1.5E+12	5.9%
		Totals	46863	1.9E+13	75.8%
	Livestock	Totals	246	2.4E+12	9.8%
	Pets	Dogs	998	9.4E+11	3.8%
	Humans	Septic Tanks	2011	1.4E+12	5.6%
		Boating	458	2.7E+11	1.1%
		Straight Pipes	52	9.6E+11	3.9%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**2.4E+13**	**100%**

Gordon Creek (Subwatershed 22)	**Wildlife**	Deer	93	4.6E+10	2.5%
		Ducks	19	4.7E+10	2.6%
		Geese	25	1.2E+12	66.3%
		Beavers	67	1.7E+10	0.9%
		Raccoons	110	1.4E+10	0.8%
		Muskrats	7995	2.7E+11	14.9%
		Totals	8308	1.6E+12	88.0%
	Livestock	Totals	26	9.3E+10	5.1%
	Pets	Dogs	27	2.5E+10	1.4%
	Humans	Septic Tanks	195	2.7E+10	1.5%
		Boating	100	6.0E+10	3.3%
		Straight Pipes	1	1.4E+10	0.8%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**1.8E+12**	**100%**
Diascund Creek (Non-Tidal) (Subwatershed 1)	**Wildlife**	Deer	434	2.2E+11	3.9%
		Ducks	63	1.5E+11	2.8%
		Geese	81	4.0E+12	72.0%
		Beavers	33	8.3E+09	0.1%
		Raccoons	449	5.6E+10	1.0%
		Muskrats	8220	2.8E+11	5.1%
		Totals	9281	4.7E+12	85.0%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	371	3.5E+11	6.3%
	Humans	Septic Tanks	268	1.9E+11	3.4%
		Boating	4	2.2E+09	0.0%
		Straight Pipes	15	2.9E+11	5.3%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**5.5E+12**	**100%**

Beaverdam Creek (Subwatersheds 2, 3)	**Wildlife**	Deer	200	1.0E+11	4.0%
		Ducks	29	6.9E+10	2.8%
		Geese	37	1.8E+12	72.2%
		Beavers	32	7.9E+09	0.3%
		Raccoons	202	2.5E+10	1.0%
		Muskrats	4274	1.5E+11	5.8%
		Totals	4773	2.1E+12	86.2%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	148	1.4E+11	5.6%
	Humans	Septic Tanks	126	8.8E+10	3.5%
		Boating	1	4.1E+08	0.0%
		Straight Pipes	6	1.2E+11	4.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**2.5E+12**	**100%**
Beaverdam Creek, UT (Subwatershed 3)	**Wildlife**	Deer	64	3.2E+10	4.1%
		Ducks	9	2.2E+10	2.8%
		Geese	12	5.8E+11	73.6%
		Beavers	11	2.7E+09	0.3%
		Raccoons	65	8.2E+09	1.0%
		Muskrats	1381	4.7E+10	6.0%
		Totals	1543	6.9E+11	87.8%
	Livestock	Totals	0	0.0E+00	0.0%
	Pets	Dogs	47	4.4E+10	5.6%
	Humans	Septic Tanks	20	1.4E+10	1.8%
		Boating	0	2.6E+08	0.0%
		Straight Pipes	2	3.7E+10	4.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**7.9E+11**	**100%**

Mill Creek (Subwatershed 11)	**Wildlife**	Deer	221	1.1E+11	2.0%
		Ducks	38	9.2E+10	1.7%
		Geese	48	2.4E+12	43.7%
		Beavers	23	5.9E+09	0.1%
		Raccoons	241	3.0E+10	0.6%
		Muskrats	6665	2.3E+11	4.2%
		Totals	7237	2.8E+12	52.2%
	Livestock	Totals	174	2.1E+12	39.0%
	Pets	Dogs	82	7.8E+10	1.4%
	Humans	Septic Tanks	400	2.6E+11	4.8%
		Boating	5	2.7E+09	0.0%
		Straight Pipes	8	1.3E+11	2.5%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**5.4E+12**	**100%**
Barrows Creek (Subwatershed 17)	**Wildlife**	Deer	192	9.6E+10	1.2%
		Ducks	25	6.0E+10	0.8%
		Geese	32	1.6E+12	19.9%
		Beavers	32	7.9E+09	0.1%
		Raccoons	133	1.7E+10	0.2%
		Muskrats	5667	1.9E+11	2.5%
		Totals	6079	1.9E+12	24.7%
	Livestock	Totals	151	4.3E+12	55.4%
	Pets	Dogs	78	7.3E+10	0.9%
	Humans	Septic Tanks	114	7.8E+10	1.0%
		Boating	2	1.2E+09	0.0%
		Straight Pipes	2	4.2E+10	0.5%
		Biosolids	2329	1.0E+12	12.8%
		SSOs	1	3.5E+11	4.5%
	Totals			**7.8E+12**	**100%**

* The results will be changed if livestock number (Table 3.13) changes after the confirmation from the counties.

Table 3.15* Summary of Bacteria Loading from Each Source in the Lower Chickahominy River Watershed by County.

County	Source		Number	Fecal Coliform Load (Counts/Day)	Percentage
Charles City (Subwatersheds 7, 16-20, 23-25)	**Wildlife**	Deer	1426	7.1E+11	2.4%
		Ducks	194	4.7E+11	1.6%
		Geese	250	1.2E+13	40.6%
		Beavers	265	6.6E+10	0.2%
		Raccoons	1320	1.7E+11	0.5%
		Muskrats	58642	2.0E+12	6.6%
		Totals	62098	1.6E+13	51.9%
	Livestock	Totals	484	9.1E+12	30.4%
	Pets	Dogs	781	7.3E+11	2.4%
	Humans	Septic Tanks	488	3.1E+11	1.0%
		Boating	402	2.4E+11	0.8%
		Straight Pipes	14	2.6E+11	0.9%
		Biosolids	6644 (tons)	2.9E+12	9.7%
		SSOs	8	8.7E+11	2.9%
	Totals			**3.0E+13**	**100%**
James City (Subwatersheds 5, 10-15, 21, 22, 26)	**Wildlife**	Deer	1314	6.6E+11	2.2%
		Ducks	250	6.1E+11	2.1%
		Geese	321	1.6E+13	53.9%
		Beavers	483	1.2E+11	0.4%
		Raccoons	1608	2.0E+11	0.7%
		Muskrats	79133	2.7E+12	9.2%
		Totals	83108	2.0E+13	68.5%
	Livestock	Totals	653	6.0E+12	20.4%
	Pets	Dogs	464	4.4E+11	1.5%
	Humans	Septic Tanks	2331	1.5E+12	5.3%
		Boating	750	4.5E+11	1.5%
		Straight Pipes	45	7.9E+11	2.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**2.9E+13**	**100%**

New Kent (Subwatersheds 1-4, 6, 8, 9)	**Wildlife**	Deer	1231	6.2E+11	3.6%
		Ducks	185	4.5E+11	2.7%
		Geese	238	1.2E+13	68.8%
		Beavers	371	9.3E+10	0.5%
		Raccoons	1256	1.6E+11	0.9%
		Muskrats	30713	1.0E+12	6.2%
		Totals	33993	1.4E+13	82.7%
	Livestock	Totals	5	3.8E+09	0.0%
	Pets	Dogs	891	8.4E+11	4.9%
	Humans	Septic Tanks	1494	1.0E+12	6.2%
		Boating	565	3.4E+11	2.0%
		Straight Pipes	37	7.0E+11	4.1%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			**1.7E+13**	**100%**

* The results will be changed if livestock number (Table 3.13) changes after the confirmation from the counties.